TECHNICAL MEMORANDUM REPORT

NO. ORDBB-TE9-30

TEMPERATURE SENSITIVITY OF THE T324E22 VIGILANTE HE CARTRIDGE-GUN SYSTEM

BY

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ARTILLERY AMMUNITION AND ROCKET DEVELOPMENT LABORATORY

FELTMAN RESEARCH AND ENGINEERING LABORATORIES

PICATINNY ARSENAL

DOVER, NEW JERSEY

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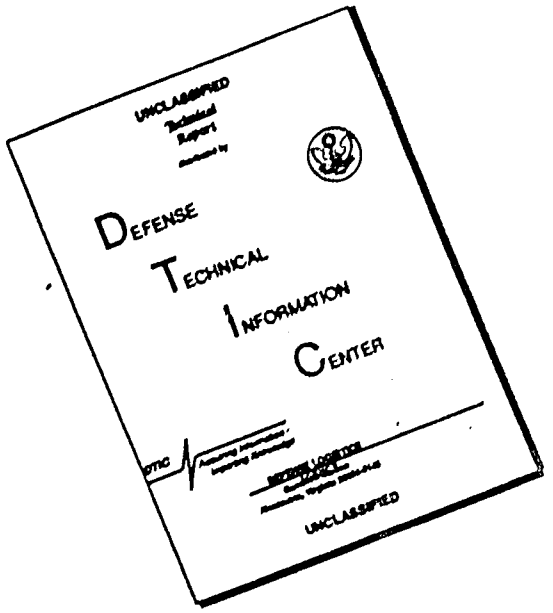

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OBJECT

To determine the relative temperature sensitivity and cook-off characteristics of the 37mm T324E22 HE cartridge and its components relative to the heating characteristics of the gun when subjected to high rates of firing.

SUMMARY

In the ground-to-air operation of the T250 gun, there should be no cook-off problem with any of the explosives or propellant elements inasmuch as all rounds are rapidly expended during the operation of the gun. However, if a round should become jammed or left in the various chambering positions during ground-to-ground operations, a cook-off problem may occur.

Recent heat tests have been completed with the individual components and the complete T324E22 HE cartridges. Results of these tests indicate that the T28E1 propellant has the lowest cook-off temperature, 239°F. The next lowest was the T300 base fuze tetryl booster lead with a temperature of 275°F. Of four cook-off tests conducted with a complete HE loaded T324E22 cartridge, the lowest cook-off temperature recorded was 262°F when the round in gun barrel was not preheated.

Results of gun firing tests of the 37mm T324E22 cartridge containing live propellant and inert HE systems were compared with results of static cook-off tests. These results indicated that the lowest temperature recorded before cook-off occurred was 237°F at the cartridge case area. This temperature was achieved with seven 48-round bursts and was 2°F below the cook-off temperature of the T28E1 propellant. At nine bursts the temperature in the same area was 250°F. The explosive MAX-2 had a cook-off temperature of 385°F when it was tested. The temperature of the area in the gun where the explosive was located after firing seven 48-bursts was 311°F maximum. After nine such bursts the temperature increased to 395°F.

CONCLUSION

No cook-off problem should exist in the T250 37mm Vigilante gun-system provided that no more than seven 48-round bursts (336 rounds) are fired continuously. If more than seven 48-round bursts are fired, the T28E1 propellant may cook-off causing the round to be fired through the tube.

RECOMMENDATION

When more than seven bursts are fired continuously, care should be exercised to insure that the muzzle of the weapon is not pointing in the direction of friendly emplacements.

INTRODUCTION

1. Cook-off is defined as the deflagration or detonation of ammunition caused by the absorption of heat from its environment. Usually it consists of the accidental and spontaneous discharge of, or explosion in, a gun or firearm, caused by an overheated chamber or barrel igniting a fuze, propellant charge, or bursting charge.

2. Cook-off may occur when a round remains in a hot gun. Before the next burst is fired, heat absorbed by the round causes the temperature of its explosive components to rise. If the temperature of an explosive component exceeds a critical value, cook-off occurs. The time between the end of firing and the occurrence of cook-off depends upon a large variety of factors which may be classified under the following headings:

a. Heat transfer and thermal properties of both gun and round.

b. The nature of the explosive components in the round.

c. The manner of firing.

d. The physical properties and dimensions of the gun and the round.

3. When cook-off occurs, the consequences may be disastrous. The automatic weapons on which these cook-off studies have been concentrated are Gatling-type guns having six barrels. The propellant, its primer, or any of the explosive components in a round may cook-off. If the propellant cooks-off with a round chambered, the projectile passes out of the barrel. The primary danger is to personnel and equipment in the line of fire. If the propellant or any explosive component cooks-off in a round in the first or second ram positions in the feed mechanism, severe damage to weapon and personnel is practically certain. If the fuze detonator cooks-off in a round in battery position but does not initiate the explosive train, there is a good probability that firing the round will clear the gun so that it remains operable although the barrel might be damaged. If the high explosive charge in the round in the chambered position is initiated, the gun will be rendered inoperable.

4. In the ground-to-air operation of the T250 gun there should be no cook-off problem with any of the explosive or propellant elements inasmuch as all rounds are rapidly expended during the operation of the gun. The rapid rate of fire is 3,000 rounds per minute. The only problem that would arise is if the gun were to be jammed with a round chambered. Also, during the ground-to-ground operations of the gun, rounds will normally be left in the various chambering positions after firing is stopped. Calculations made by the Armour Research Foundation indicated that there is a possibility of there being a cook-off problem when the gun is used for this type of operation. Recommendations were made to Sperry Gyroscope Company, the prime contractor

for the Vigilante system, that modifications be made in the firing mechanism so that, in ground-to-ground operations, the last fully chambered round would be fired when firing ceases. This should significantly reduce the possibility of cook-off. However, it was still necessary to determine whether the heat generated during the firing of the gun would be sufficient to cook-off rounds jammed during air-to-air firings and partially chambered rounds during ground-to-ground firings.

5. This report contains the results of temperature sensitivity tests conducted with the X-1 model and the pilot model No. 3 of the T250 gun. In addition, cook-off temperatures of complete rounds and their components are given. The latter information was obtained by tests conducted at National Northern Division under Contract ORD-5096, Task No. 8.

RESULTS

6. Gun-firing results of the X-1 experimental model of the T250 gun were unsatisfactory because of excessive jamming and failure of the parts to work properly. Tests were discontinued with this gun.

7. Five separate tests were conducted by National Northern Division to determine the cook-off temperature of the complete round and individual round components as follows:

Test No.	Item
1	Complete round submerged into a hot salt bath and temperature stabilized at approximately 300°F.
2	Complete round in an unheated T250 gun barrel and temperature raised and stabilized at approximately 262°F.
3	Complete round inserted so that seven inches of the round was extended from the gun barrel and both items heated until cook-off occurred.
4	Complete round inserted into a heated gun barrel at approximately 284°F and temperature increased until cook-off occurred.
5	Individual components of the complete round were placed in a heated oven at various temperatures. If cook-off did not occur, the temperature was raised until it did.

The results of the above tests are detailed in Tables 1 and 2.

DISCUSSION OF RESULTS

8. Two inert loaded 37mm T324E22 rounds were equipped with thermocouples (Figure 1). Because of the inaccessibility at the rear of the gun tube, these thermocouple wires could not be brought out through the base of the shell. The projectile was modified to bring the wires through the nose and to allow them to be ultimately connected to the temperature recorder (Figure 2). To connect these wires to the recorder, a long aluminum pole was made with a plug on one end which mated with the plug on the shell. Both the plugs on the shell and pole were keyed to permit ease of assembly (Figure 4). In this way, a shell could be placed in any desired chambering position, the pole inserted through the muzzle end of the gun barrel and connected to the shell. Thus, the heat build-up at any of the instrumented points could be recorded. This set-up was used for the X-1 and Pilot Model No. 3 guns. In addition, an extra thermocouple was assembled to record the outside air temperature on the recorder when the firings were conducted.

9. A sequence of firing was recommended by both the Armour Research Foundation and the Springfield Armory to create the highest build-up in the X-1 model of the T250 gun. This sequence involved firing four bursts of 12 rounds each as rapidly as possible, inserting an instrumented round and recording the maximum round temperatures. Prior to the initial firings, it was decided to conduct the test under high ambient temperature conditions. The gun and ammunition would be conditioned to 150°F. Difficulty, however, was encountered in obtaining 150°F. The maximum temperature which was obtained was 130°F. Firing was therefore conducted at this point.

10. The first series of firings with the X-1 model at 130°F resulted in failures. The gun jammed after several attempts to fire were made. The failures were attributed to the feed mechanism being damaged and the hydraulic mechanism leaking and not operating correctly. No further testing was conducted and the X-1 model gun was shipped to the Springfield Armory.

11. During July 1959, a second attempt was made to continue the heat build-up tests using the repaired X-1 model gun. After 100 rounds had been satisfactorily fired, it was decided to fire bursts of only 24 rounds as this would put less strain on the gun. Ten bursts of 24 rounds each (240 rounds) and 12 bursts (288 rounds) were to be initially conducted. After a total of 165 rounds were fired, the gun jammed. When the gun jammed, the conditions were such that the gun could not be rotated nor the instrumented round placed in any of the chambering positions. Since it was decided to obtain as much data as possible, the instrumented round was inserted into the chamber at the 12 o'clock position and the aluminum pole assembled to the shell. The results show that the maximum temperature obtained after firing 12 bursts (288 rounds) was approximately 210°F at the bourrelet area of the shell. Additional attempts were made to fire a larger number of bursts and each attempt resulted in jamming of the gun. No further testing was conducted with the X-1 model of the T250 gun.

12. During August 1959, at the Vigilante Committee Meeting, it was decided to conduct cook-off tests with the complete T324E22 round and components of the round in order to determine their cook-off temperatures. National Northern Division was requested under Contract ORD-5096, Task No. 8 to conduct this series of tests as described in paragraph 7. Results in Table 1 show that for Test Number 1, the live T324E22 round exploded after submersion in the hot salt bath for 16 minutes at 300°F. It was concluded that the T300 base fuze could have cooked-off in this test. Results of tests of the individual components of the base fuze show that the tetryl pellet may have cooked-off. In Test No. 3, after 145 minutes at a temperature of 401°F, cook-off occurred. Fragments of the projectile remained in the gun barrel and fragments of the cartridge case were scattered around the test area. For Test No. 4, the round cooked-off 72.8 minutes after insertion in the gun barrel at a temperature of 302°F. Very little propellant was recovered in the test area. In both of these tests, no conclusion could be drawn as to why cook-off occurred. Table 2 details results of Test No. 5. In this test, the propellant cooks-off at a temperature of 239°F after 18.8 minutes. Table 9 shows that the highest temperature obtained was 250°F at the cartridge case area after 9 bursts of firing (432 rounds). The results of the last series of firings show that a cook-off problem exists if more than seven bursts are fired continuously.

13. During January 1960, heat build-up tests were continued at Aberdeen Proving Ground. A new model T250 gun (Pilot Model No. 3) was used. Two bursts of 48 rounds each (96 rounds) were fired, an instrumented round inserted into the chamber and the temperature recorded. Table 3 shows that thermocouple No. 6 at the bourrelet area of the shell reached a maximum temperature of 179°F. The tests were discontinued due to erratic behavior of the parts in the gun.

14. Tests using the Pilot Model No. 3 gun were continued during March 1960 after the T250 gun was repaired. From 3 to 9 bursts of 48 rounds per burst were fired. Tables 4 through 8 detail the results. The maximum temperature reached with 9 bursts was 395°F (thermocouple No. 6) at the bourrelet area of the shell. It should be noted that during the heat build-up tests to date, all maximum temperatures were in the bourrelet area of the shell. This is because of the greatest concentration of heat at the portion of the gun in this area. MAX-2, the explosive composition used in this round, has a cook-off temperature of 374°F. This is below the 395°F obtained in the shell. It is highly improbable that more than seven bursts will be fired continuously in this system.

15. The temperature build-up results of the gun firing tests of the T250 gun indicate that seven continuous bursts do not create a cook-off problem, whereas nine bursts do. At seven bursts (see Table 7), all explosive components appear safe from cook-off if a round is jammed or remains in the chamber after firing. The regions of highest temperature build-up occurred at the bourrelet area of the shell (explosive filler area) and the base fuze area. If more than seven bursts are fired continuously, as shown in

Table 8, it is probable that cook-off may occur in either the propellant, base fuze or explosive filler areas. All three areas would be within or over the cook-off temperature range. Since the T28E1 propellant has the lowest cook-off temperature (Table 2), when more than seven bursts are fired continuously, care must be exercised to insure that the muzzle of the weapon is not pointing in the direction of friendly emplacements. The propellant will cook-off and discharge the round.

EXPERIMENTAL PROCEDURE

16. The following equipment was used for the gun firing test to determine temperature build-up:

a. Weston Multiple - Point Recorder, Model 6705 (Figure 2).

b. Aluminum pole with female thermocouple attachment (Figure 3).

c. Shell T324E22 with male thermocouple and adapter (Figures 4 and 5).

17. The T324E22 shell were assembled with six thermocouples located as shown in Figure 1. The thermocouple wires were placed at locations determined were the highest temperature build-up would occur.

18. A Weston 8-point multiple recorder (Figure 2) was placed inside the testing barricade. Wires from the aluminum pole to the recorder were strung through the barricade inside a protective steel pipe.

19. Immediately after firing the bursts, the instrumented T324E22 cartridge was inserted into the chamber. The female connector attached to a long aluminum pole was then inserted into one of the firing tubes (Figure 7).

20. Loading of the T324E22 practice cartridges into the T250 magazine were done by hand. A clip of 6 rounds was inserted into the ammunition drum and sufficient clips were added to conduct the number of bursts to be fired. A fully loaded drum (144 rounds) is shown in Figure 6 prior to firing.

21. All rounds used throughout the heat build-up test were T324E22 practice cartridges with dummy fuzes. The filler was inert and the live components consist of the T104E8 electric primer and T28E1 propellant.

22. Test firings were conducted at Camp Wellfleet, Wellfleet, Massachusetts with the X-1 gun and Aberdeen Proving Ground with the Model Pilot No. 3 gun.

23. Cook-off tests of HE loaded 37mm T324E22 cartridge were conducted by National Northern Division of American Potash and Chemical Corporation.

The first series of tests involved the complete round immersed in a salt bath containing 52/48 potassium nitrate/sodium nitrate and the bath heated with Cal-Rod heaters to approximately 302°F (Figure 8). The second series of tests involved the cartridge placed into a T250 gun barrel wrapped with nichrome wire heating coils. Three thermocouples were placed on the outside of the cartridge as follows:

a. 4 inches above the primer head on the cartridge case

b. 7-3/4 inches above primer head on the cartridge case

c. 1-½ inches from the front-end of the nose fuze (Figure 9).

Heat was applied starting at ambient temperature (60.8°F). The temperature was to be increased in increments of 10°F every 15 minutes till the round cooked-off. Erratic temperature control resulted and at 255°F the temperature was stabilized. In the third series of tests, the round was partially chambered in the gun barrel. Both the complete round and gun barrel were heated until cook-off occurred (Figure 10). The fourth series of tests involved the round inserted into a preheated gun barrel (three hours of heating) and cook-off recorded (Figure 11). The remaining components of the complete round (Table 2) were placed in a preheated oven (Figures 12 and 13) and the temperature raised to a probable cook-off temperature and held for approximately 30 minutes. If no cook-off occurred, the item was again placed in the oven at a higher temperature till cook-off occurred. Time measurements were recorded in all cases.

ACKNOWLEDGEMENT

Acknowledgement is extended to National Northern Division of American Potash and Chemical Corporation for preparing and testing of the 37mm T324E22 HE cartridge and components for the cook-off studies. Acknowledgement is also extended to the Instrumentation Section, Technical Services Laboratory, FREL of Picatinny Arsenal for preparing instrumented cartridge and setting-up of instrumentation for the gun-firing tests. Messrs. S. D. Stein and B. J. Zlotucha of Picatinny Arsenal contributed time and effort to the solution of the problem reported herein.

TABLE 1

RESULTS OF LIVE-LOADED T324E22 CARTRIDGE COOK-OFF TESTS[a]

Test No.	Time, Minutes	Thermocouple No., °F[c] 1	2	3	Remarks
1[b]	Start	295	307	302	Round inserted in salt bath
	5	302	302	293	
	10	300	297	291	
	16	300	300	298	Cooked off
2[b]	Start	61	61	61	
	10	106	131	181	
	25	221	212	212	
	40	275	248	230	
	50	284	259	230	
	60	282	266	237	
	70	275	266	248	
	85	275	266	253	
	95	266	266	255	
	105	264	264	255	
	111	261	262	257	Cooked off. Fragments of projectile widely scattered.
3[b]	Start	71	71	71	
	12	80	87	71	
	30	118	149	71	
	50	177	203	71	
	60	210	230	71	
	70	237	249	71	
	80	267	273	71	
	90	291	291	73	
	100	314	305	75	
	110	338	321	75	
	120	357	334	77	
	130	377	348	78	
	140	392	359	80	
	144	399.2	361.4	80	
	146	401	---	—	Cooked off. Fragments of cartridge case widely scattered.

TABLE 1 (Cont)

Test No.	Time. Minutes	Thermocouple No., °F[c] 1	2	3	Remarks
4[b]	Start	262	284	302	
	10	262	284	302	
	25	264	284	302	Round inserted in gun barrel
	30	249	276	302	
	40	246	269	300	
	50	246	271	298	
	55	246	271	298	30 Minutes after insertion
	60	248	273	300	
	70	249	273	300	
	80	253	276	300	
	90	255	276	300	
	96	257	278.6	300	
	97.8	---	---	302	Cooked off. Propellant recovered in test room.

[a]Tests conducted at National Northern Division of American Potash and Chemical Corp.

[b]For the tests, see paragraphs 8 and 24; Figures 7 through 10

[c]See Figures 7 through 10

TABLE 2

RESULTS OF COOK-OFF TESTS[a] OF THE COMPLETE 37MM T324E22 CARTRIDGE AND INDIVIDUAL COMPONENTS

Cartridge	Cook-off Temperature, °F	Cook-off Time, Minutes[b]
Conditioning Environment		
Salt Bath	300.2	16
Gun Barrel, not Preheated	262.4	111
Gun Barrel, Cartridge Partially Chambered	401.0	146
Gun Barrel Preheated	302.0	97.8
Base, Fuze (T300) Components (tested in preheated oven)		
Secondary Primer	345	1.7
T98 Percussion Primer	327	1.3
T56 Flash Detonator	336	7.6
Tetryl Booster Lead (Unconfined)	275	30.0 (Decomposed)
Complete Base Fuze	302	30.0 (No cock-off)
Nose Fuze (PD, T231E3) Components (tested in preheated oven)		
M29A1 Primer	528	2.4
T85E1 Stab Detonator	374	13.1
Tetryl Booster	390.2	15.5
Complete Nose Fuze	365[c]	43.1

TABLE 2 (Cont)

Units	Cook-off Temperature, °F	Cook-off Time, Minutes[b]
T104E8 Primer Assembly (tested in preheated oven)		
Head Assembly	401	9.8
Loading Assembly	518	27.5
Primer Complete	509	76.9
Tracer	564	30 (No cook-off, composition partly melted)
T28E1 Propellant[d]	239	18.8
MAX-2 (Loaded into 20mm Round)	384.8	17.7
PETN Relay Assembly	329	6.8

[a]Tests conducted at National Northern Division of American Potash and Chemical Corp.

[b]Refers to minutes to cook-off from the time component was inserted in preheated oven.

[c]For the test, the tetryl booster cooked off.

[d]Propellant consisted of 48 grams wrapped in aluminum foil with a thermocouple in the center of the charge.

TABLE 3

RESULTS[a] OF TWO-48 ROUND BURSTS[b]

Time, Minutes	Thermocouple No.[c], °F						Air Temp, °F Avg.
	1	2	3	4	5	6	
3	47	49	76	77	84	95	
6	48	56	90	104	114	133	
9	58	70	104	127	137	159	
12	66	80	114	144	152	171	
15	74	85	120	153	159	177	49
18	76	89	122	156	161	179	
21	79	92	123	155	161	175	
24	80	94	123	155	159	172	
25.5	81	94	122	153	157	170	

[a]Tests conducted at Aberdeen Proving Ground using the Pilot Model #3 T250 gun.

[b]Immediately after the burst was fired an instrumented T324E22 inert cartridge was inserted into the chamber and the temperature recorded.

[c]Position of thermocouple is shown in Figure 1.

TABLE 4

RESULTS[a] OF THREE 48-ROUND BURSTS[b]

Time Minutes	Thermocouple No.[d] 1	2	3	4[c]	5[c]	6	Air Temp., °F Avg.
2	25	30	60	---	---	80	
4	26	32	70	---	---	110	
6	30	43	85	---	---	138	
8	40	57	95	---	---	158	
10	50	64	105	---	---	170	
12	55	70	110	---	---	175	38
14	59	75	111	---	---	180	
16	60	78	140	---	---	181	
18	64	80	142	---	---	180	
20	68	82	140	---	---	179	
22	70	85	139	---	---	176	

[a]Tests conducted at Aberdeen Proving Ground using the Pilot Model #3 T250 gun.

[b]Instrumented T32E22 inert cartridge weschambered immediately after firing of bursts.

[c]Thermocouple numbers 4 and 5 revealed an open circuit during temperature recording.

[d]Position of thermocouples shown in Figure 1.

TABLE 5

RESULTS[a] OF FOUR 48-ROUND BURSTS[b]

Time Minutes	Thermocouple No.[c] °F						Air Temp. °F Avg.
	1	2	3	4	5	6	
2	25	30	70	46	63	80	
4	27	36	86	80	96	124	
6	35	54	104	114	130	159	
8	48	67	117	142	155	185	
10	57	77	128	160	171	203	38
12	65	86	135	173	183	210	
14	70	90	137	180	190	215	
16	73	95	140	185	192	216	
18	75	98	140	186	195	215	
20	76	100	140	186	181	214	

[a]Tests conducted at Aberdeen Proving Ground using the Pilot Model #3 T250 gun.

[b]Instrumented T324E22 inert cartridge was chambered immediately after firing of bursts.

[c]Position of thermocouples shown in Figure 1.

TABLE 6

RESULTS[a] OF FIVE 48-ROUND BURSTS[b]

Time Minutes	Thermocouple No.[c] °F 1	2	3	4	5	6	Air Temp. °F Avg.
2	35	60	123	76	90	104	
4	45	71	135	116	132	150	
6	55	84	146	153	163	193	
8	67	99	160	183	190	220	
10	79	110	189	203	205	240	
12	84	114	197	215	211	252	39
14	90	119	202	219	214	257	
16	94	122	205	224	214	257	
18	97	124	206	225	211	256	
20	100	125	202	224	209	254	

[a]Tests conducted at Aberdeen Proving Ground using the Pilot Model #3 T250 gun.

[b]Instrumented T324E22 inert cartridge was chambered immediately after firing of bursts.

[c]Position of thermocouples shown in Figure 1.

TABLE 7

RESULTS[a] OF SEVEN 48-ROUND BURSTS[b]

Time Minutes	Thermocouple No.[c] °F 1	2	3	4	5	6	Air Temp. °F Avg.
2	45	52	119	95	122	134	
4	52	72	154	144	160	190	
6	60	88	185	185	194	240	
8	65	98	209	211	216	270	
10	70	105	223	230	234	290	39
12	72	110	231	245	240	305	
14	76	114	235	255	243	311	
16	79	117	237	260	245	311	
18	83	121	237	262	246	310	
20	87	122	237	264	246	309	

[a] Tests conducted at Aberdeen Proving Ground using the Pilot Model #3 T250 gun.

[b] Instrumented T324E22 inert cartridge was chambered immediately after firing of bursts.

[c] Position of thermocouples shown in Figure 1.

TABLE 8

RESULTS[a] OF NINE 48-ROUND BURSTS[b]

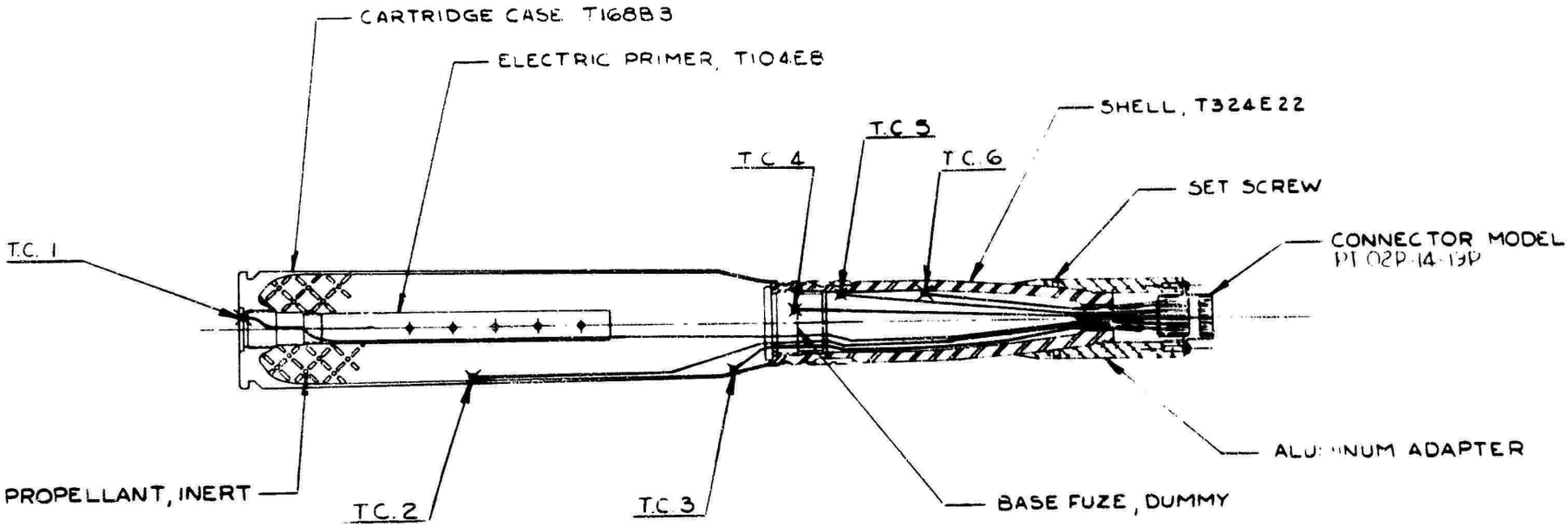
Time Minutes	Thermocouple No.[d] °F 1	2	3	4	5[c]	6	Air Temp °F Avg.
2	55	85	180	121	142	165	
4	68	102	204	190	209	244	
6	84	122	221	244	254	309	
8	95	136	239	283	303	353	
10	105	145	244	309	---	385	39
12	112	155	246	324	---	390	
14	117	160	249	332	---	395	
16	118	165	250	335	---	393	
18	120	167	250	333	---	389	
20	124	170	249	331	---	380	

[a] Tests conducted at Aberdeen Proving Ground using the Pilot Model #3 T250 gun.

[b] Instrumented T324E22 inert cartridge was chambered immediately after firing of bursts.

[c] Thermocouple number 5 received on open circuit after 8 minutes of recording.

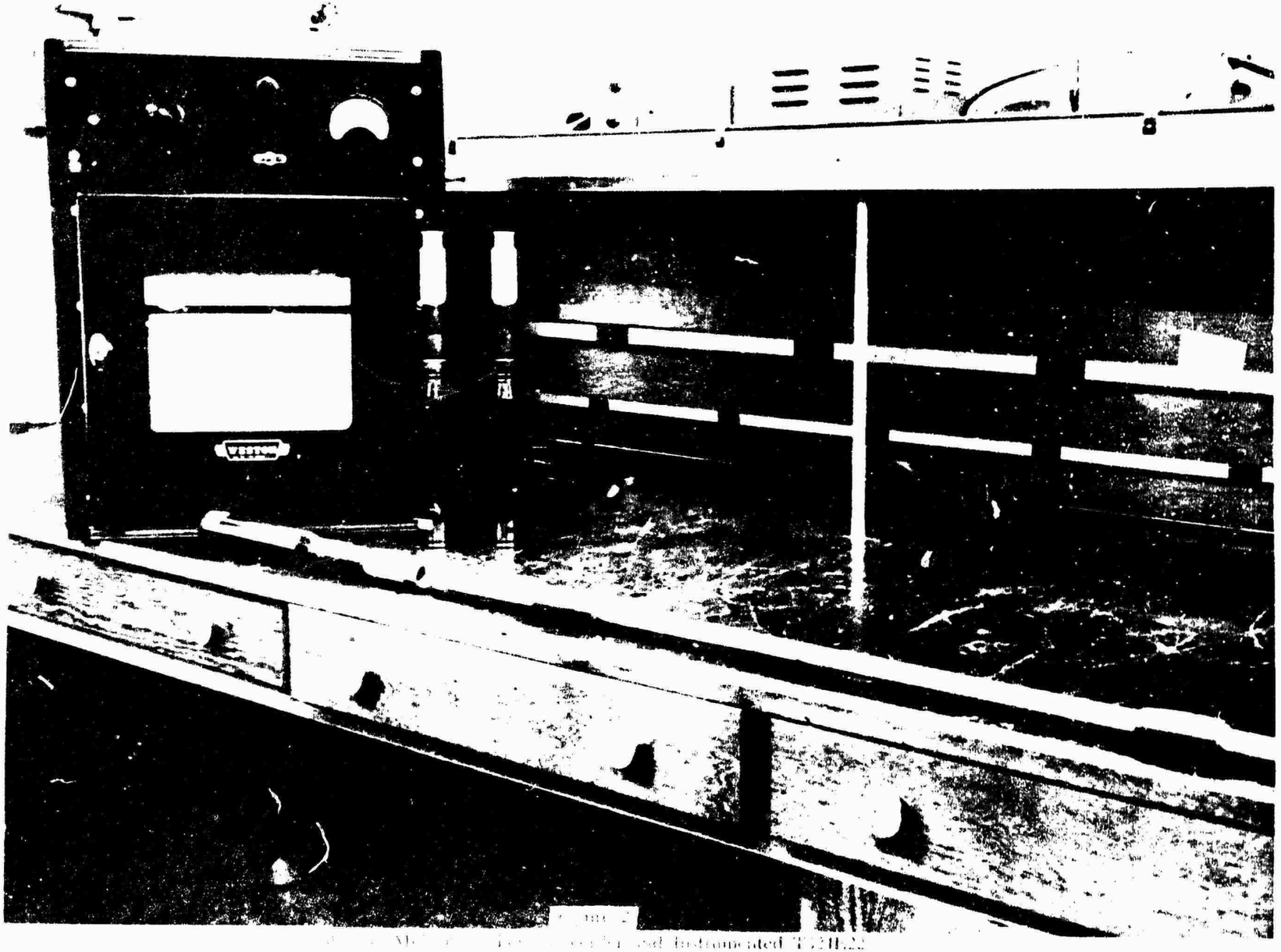
[d] Position of thermocouples shown in Figure 1.



NOTE:
INSTRUMENTED CARTRIDGE IS CHAMBERED IMMEDIATELY AFTER FIRING OF BURSTS

LOCATION OF THERMOCOUPLES AND COMPONENTS OF 37MM T324E22 INSTRUMENTED CARTRIDGE

FIGURE - 1



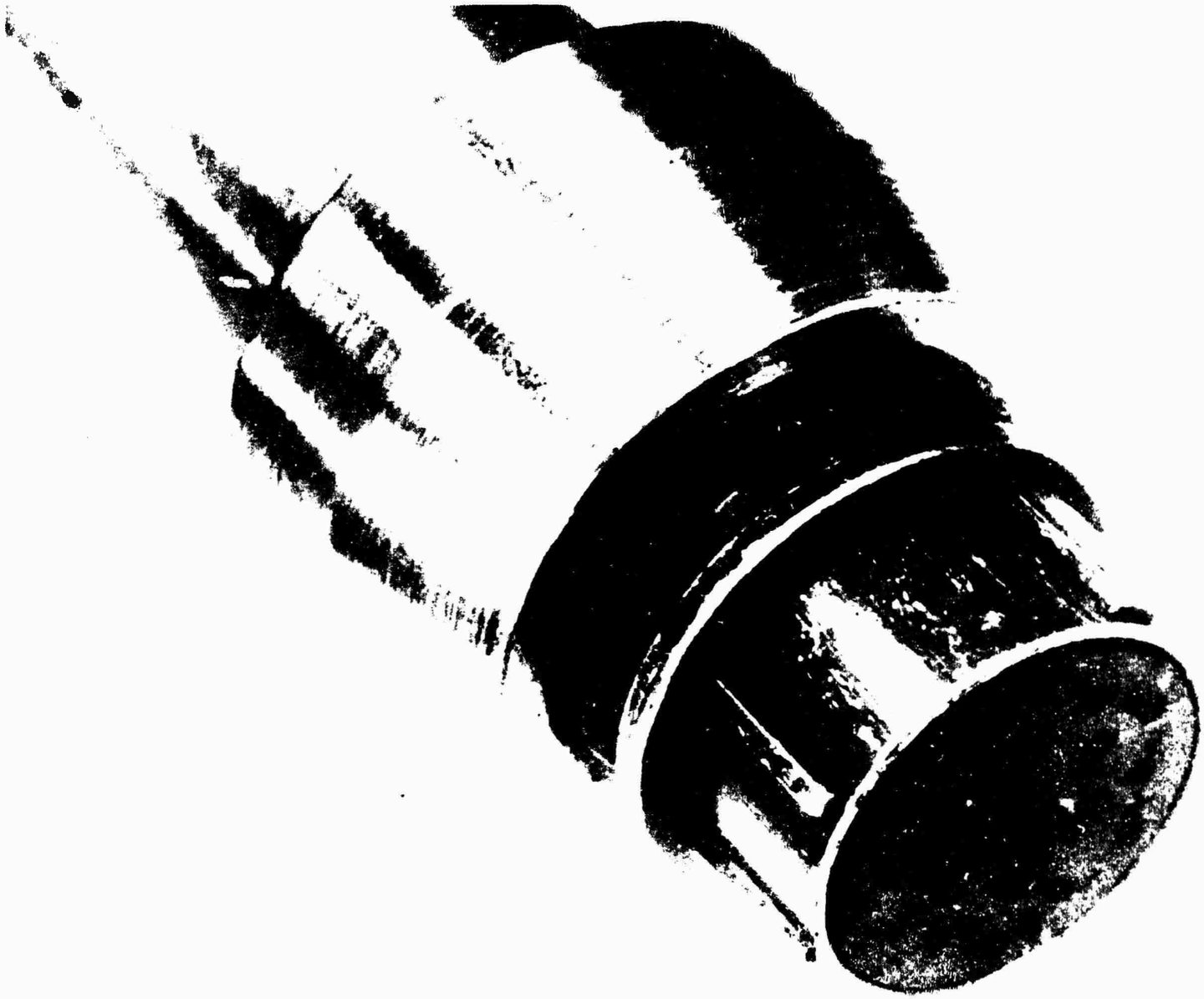


Figure 3
Female Thermocouple Attachment Assembled To Aluminum Pole

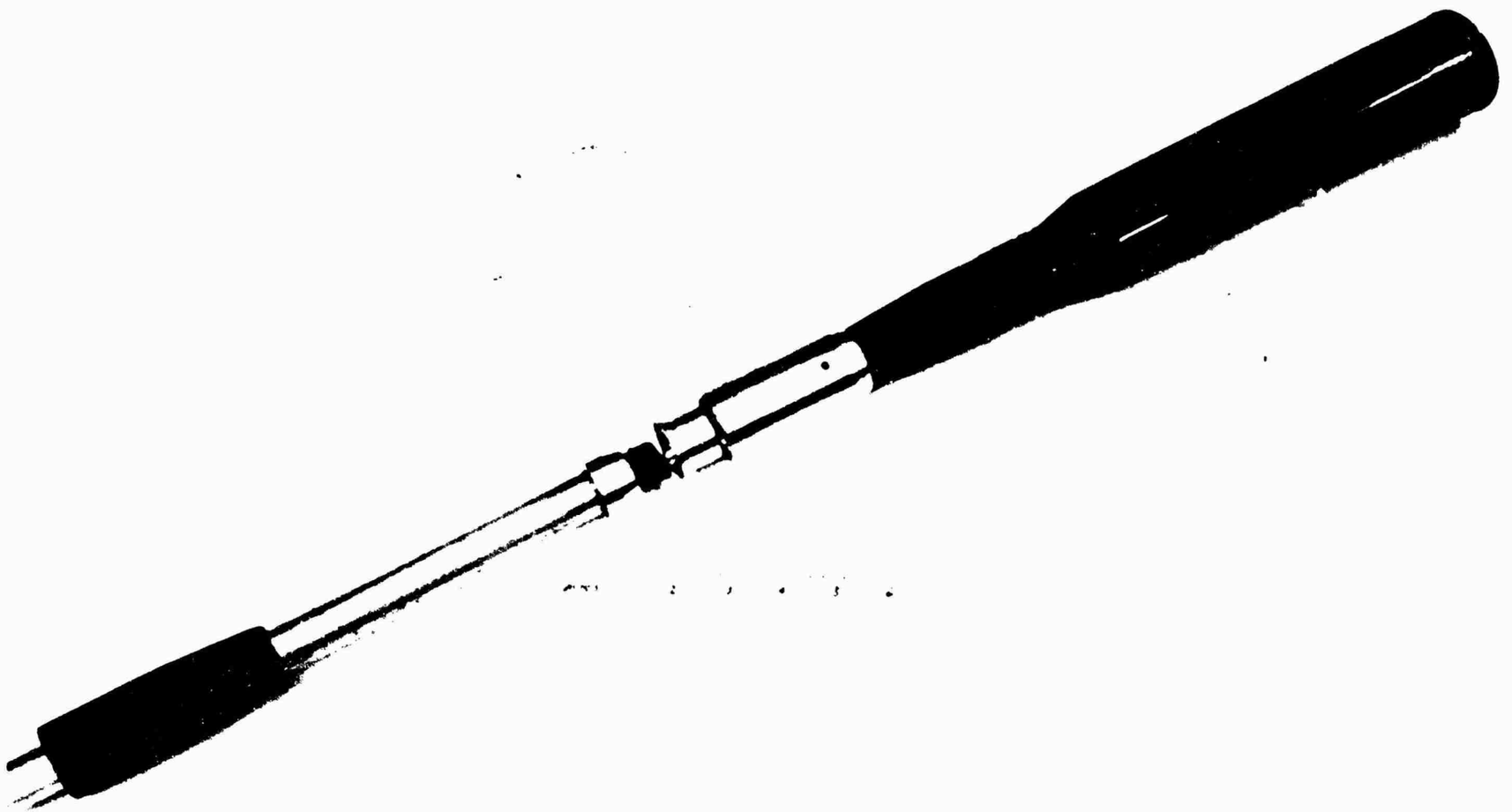


Figure 4
T324E22 Shell with Male Adapter and Female Connector
Attached To Aluminum Pole.

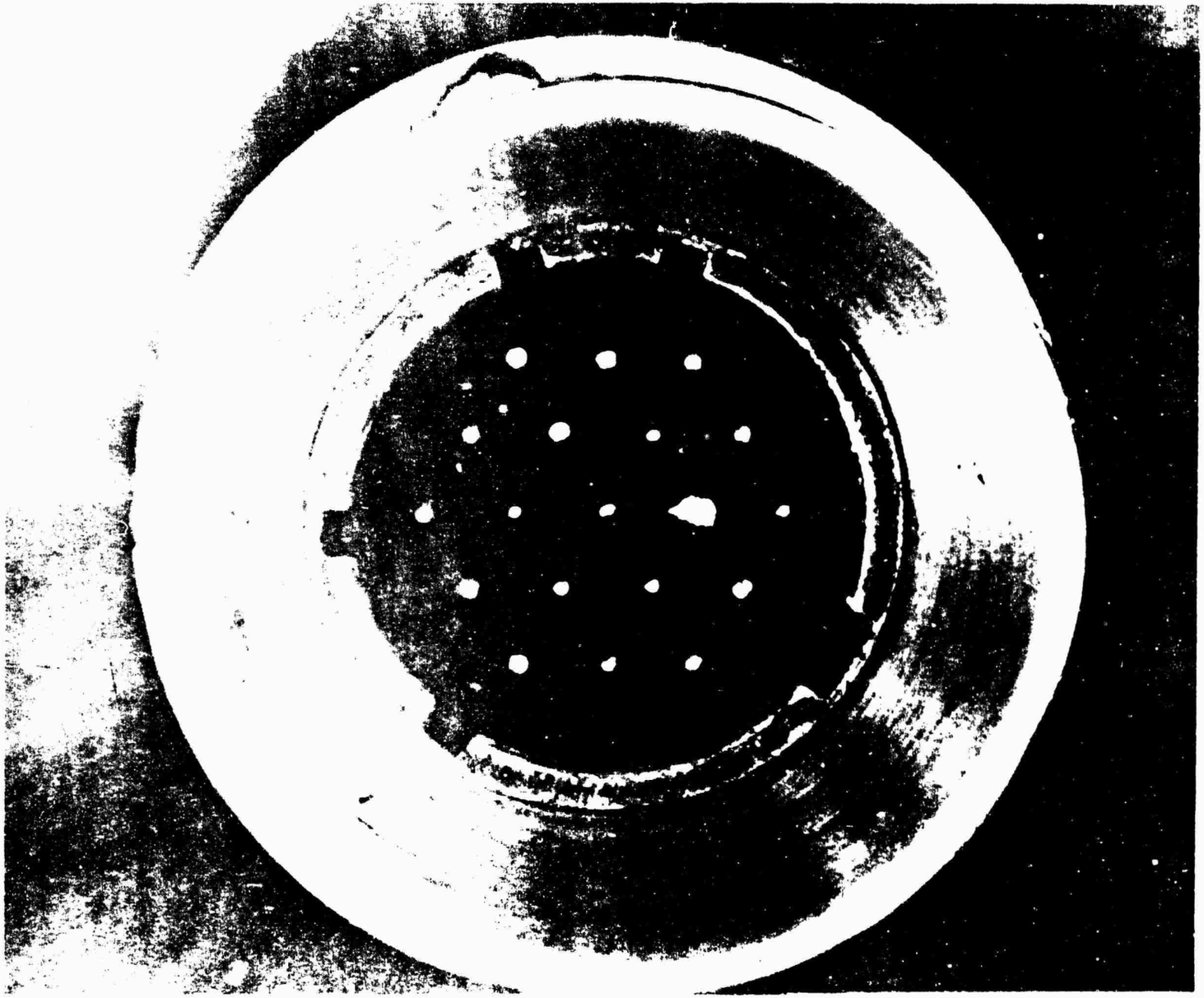


Figure 5
M-1 Magnet Assembled To T324E22 Shell.

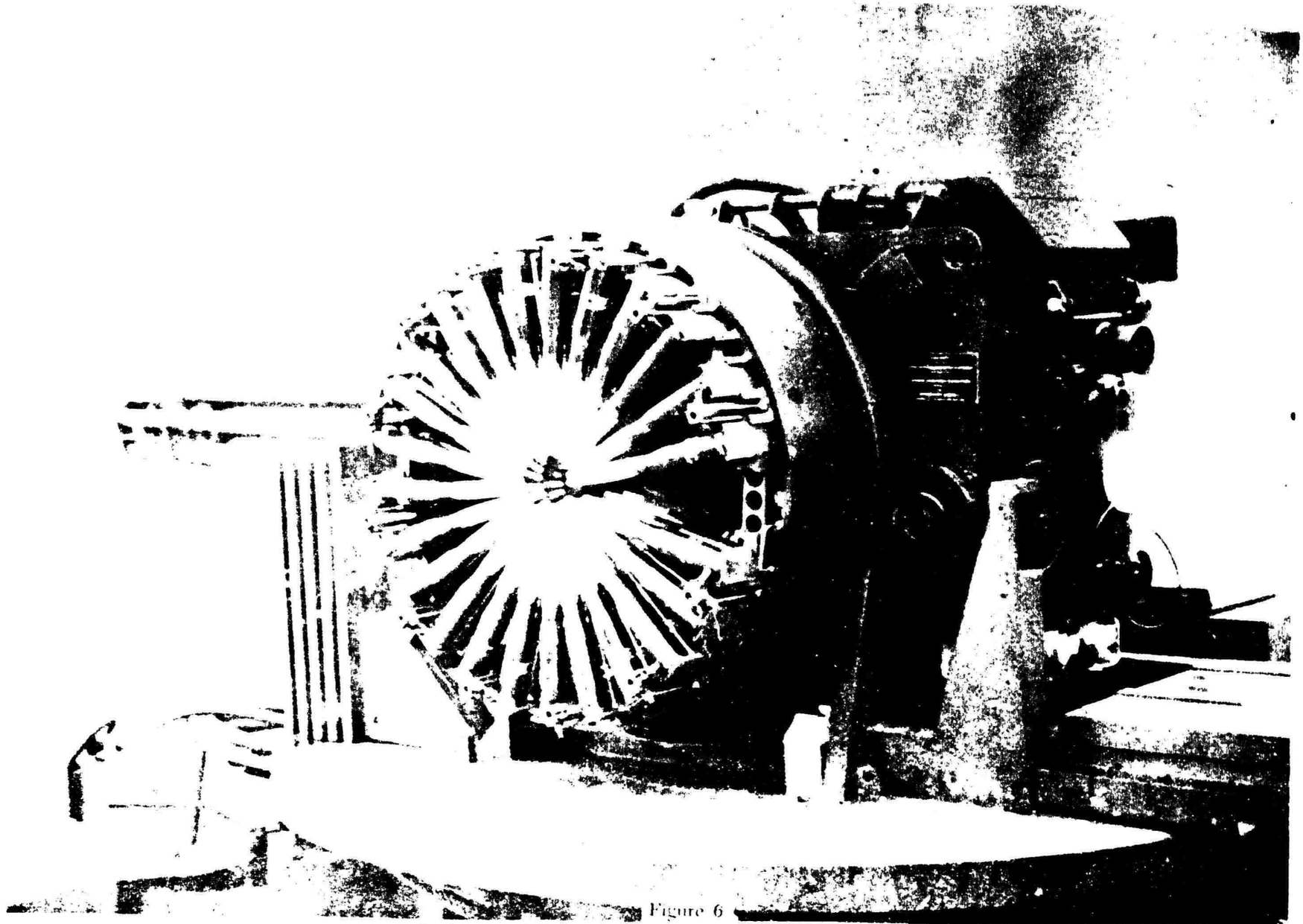


Figure 6
Fully Loaded 1250 Can containing 141 T32HE22 Inert Cartridges

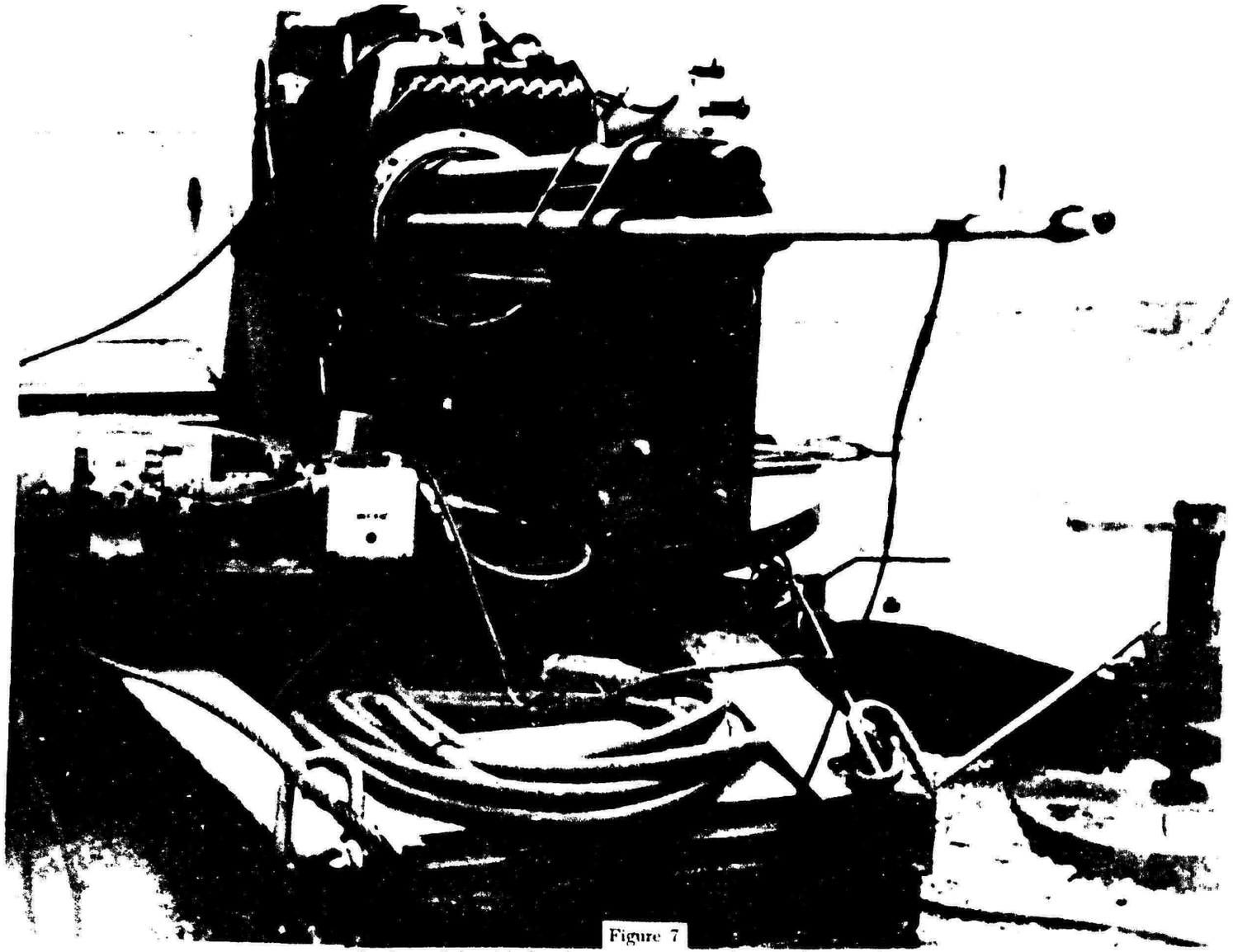
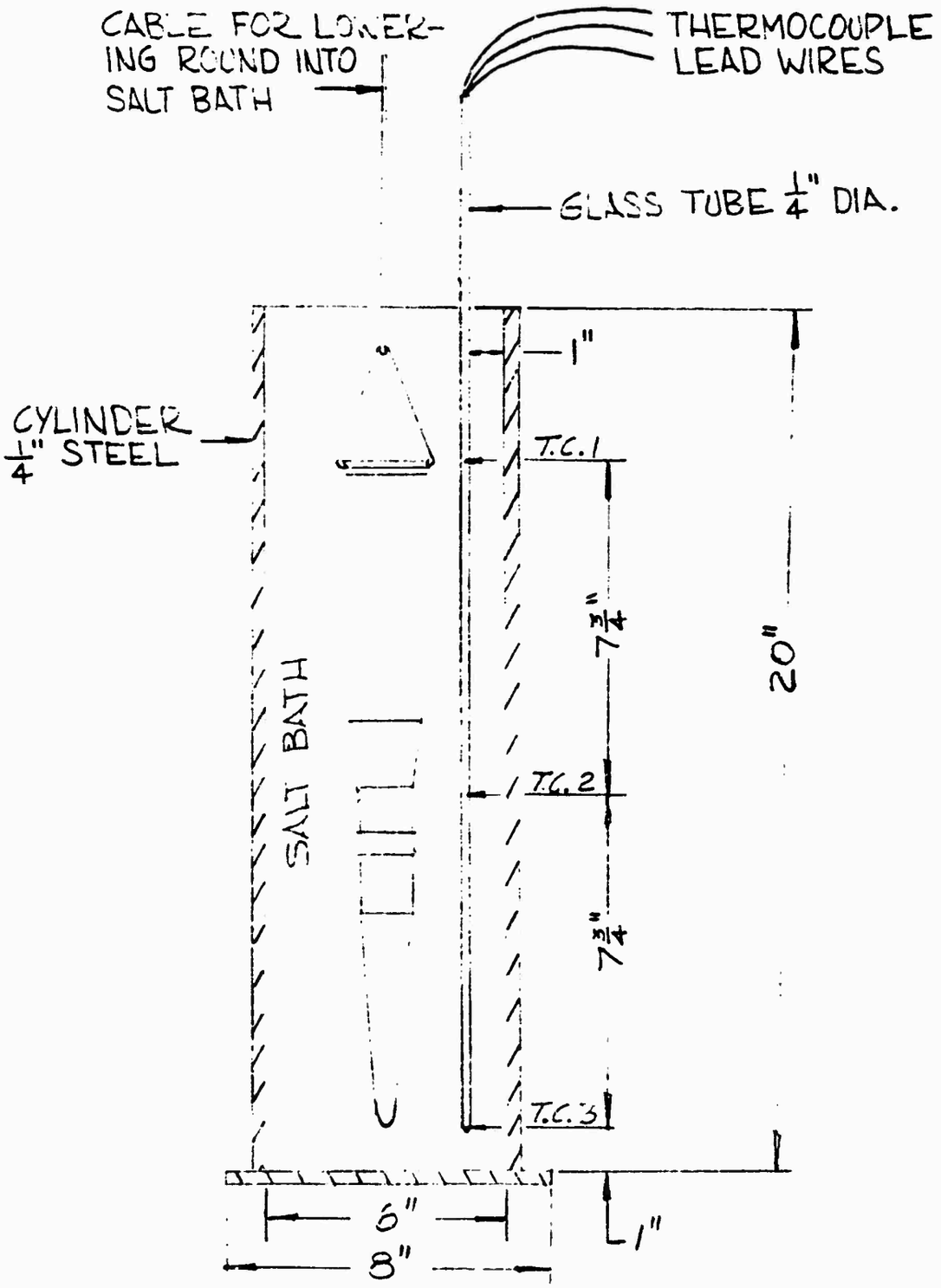


Figure 7

Aluminum Pole with female connector inserted into tube to ~~make~~ with instrumented T324E22 cartridge

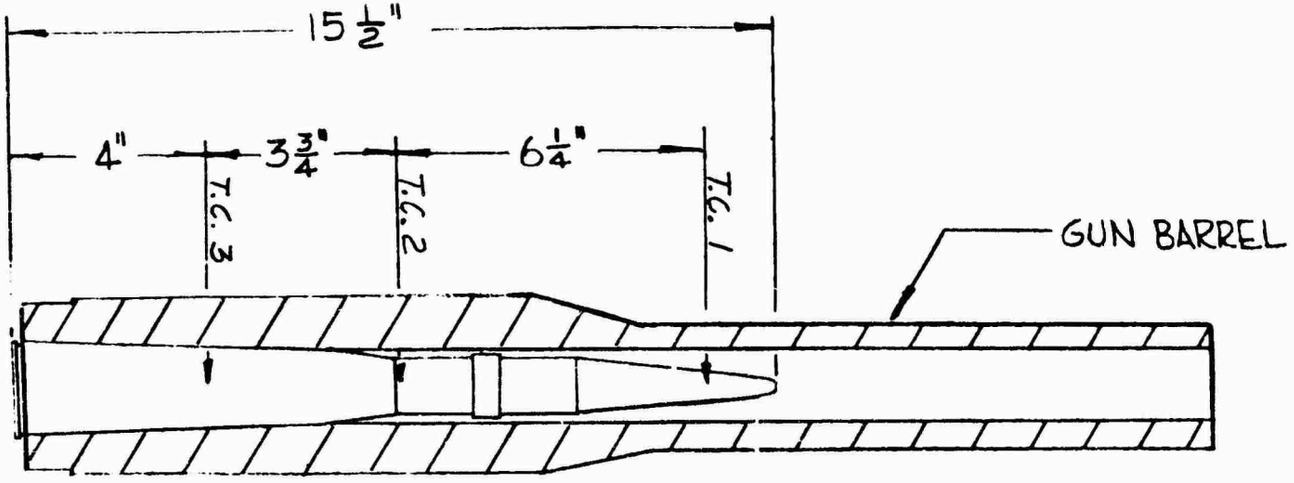
NOTE wires at end of pole leading to Weston recorder to measure heat build up of cartridge



CYLINDER WRAPPED WITH THREE 1000 WATT CALROD HEATING UNITS AND INSULATED.

FIGURE 8

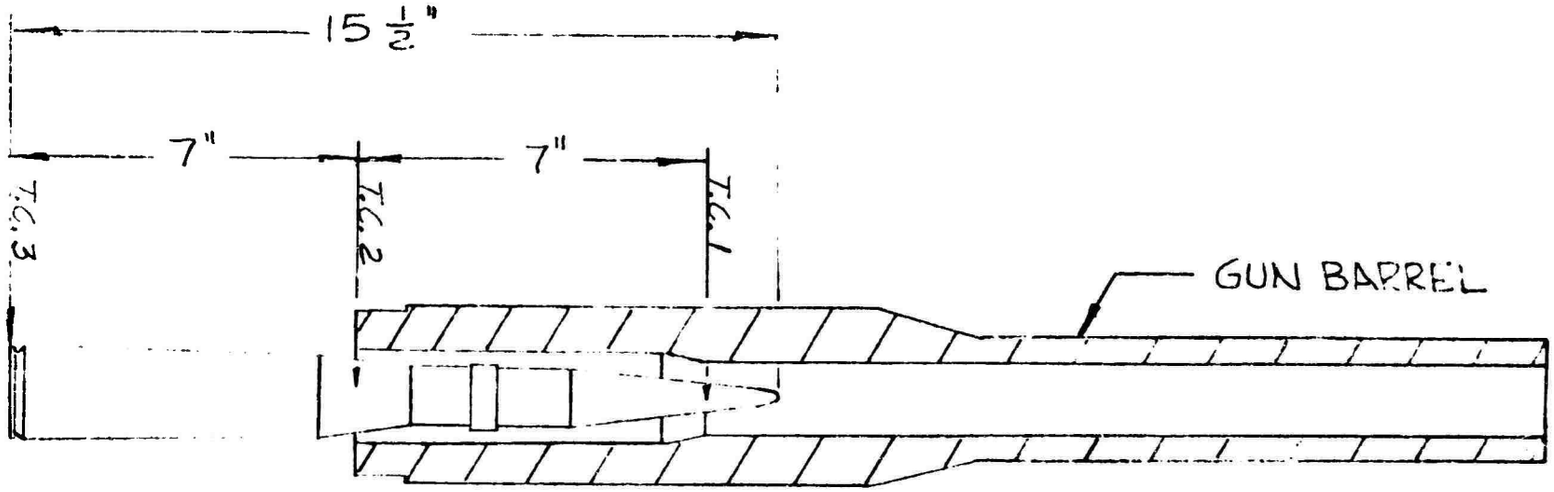
SET-UP FOR COOK-OFF TESTS OF 37MM ROUND IN SALT BATH (VERTICAL)



GUN BARREL WRAPPED WITH HEATING COIL AND INSULATED. THERMOCOUPLES ON SURFACE OF ROUND.

FIGURE 9

SET-UP FOR COOK-OFF TESTS OF 37MM ROUND NOT PREHEATED (HORIZONTAL)



GUN BARREL WRAPPED WITH HEATING COIL AND INSULATED. THERMOCOUPLES ON SURFACE OF ROUND.

FIGURE 10

SET-UP FOR COOK-OFF TESTS OF 37MM ROUND PARTIALLY CHAMBERED (HORIZONTAL)

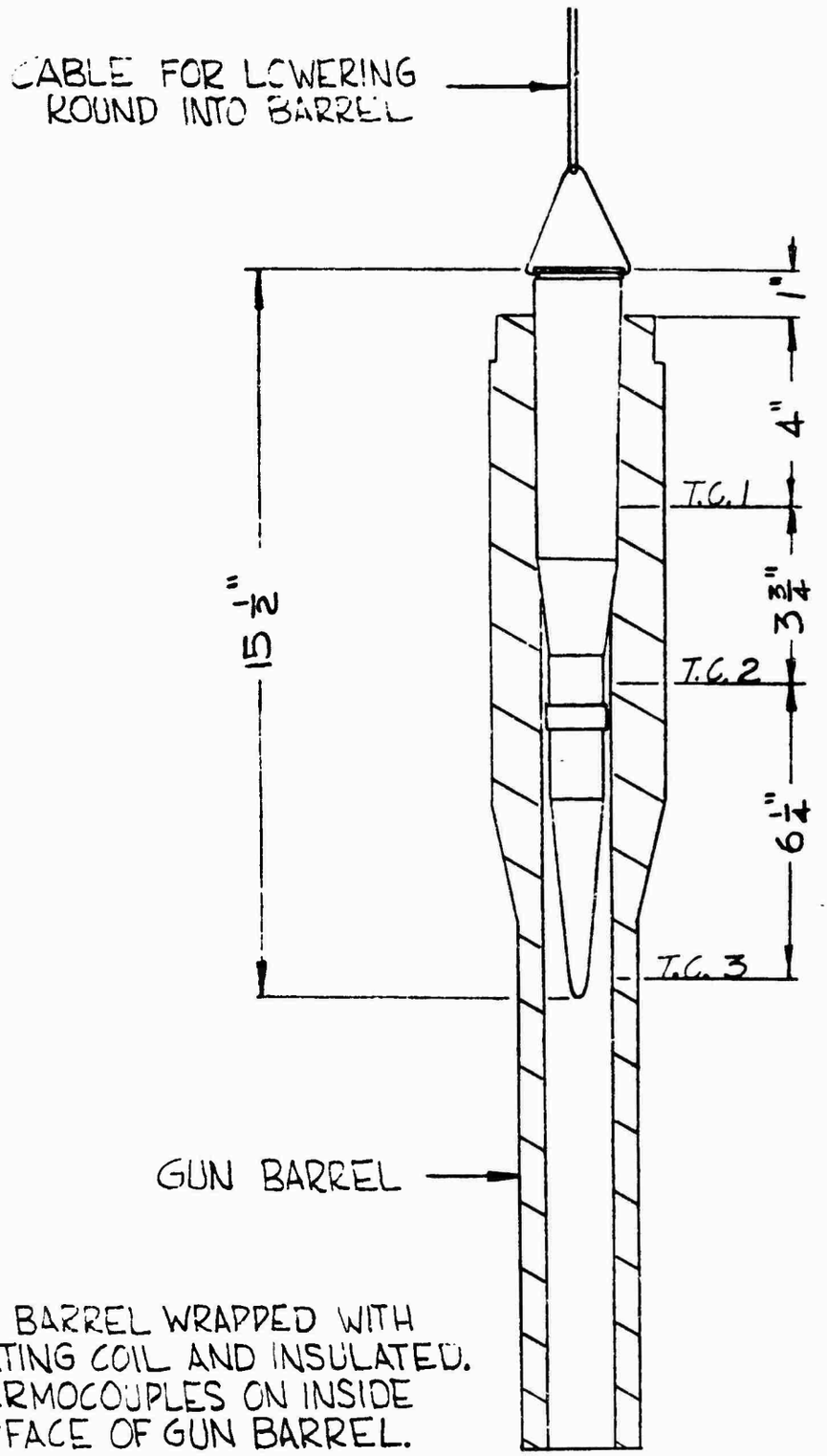
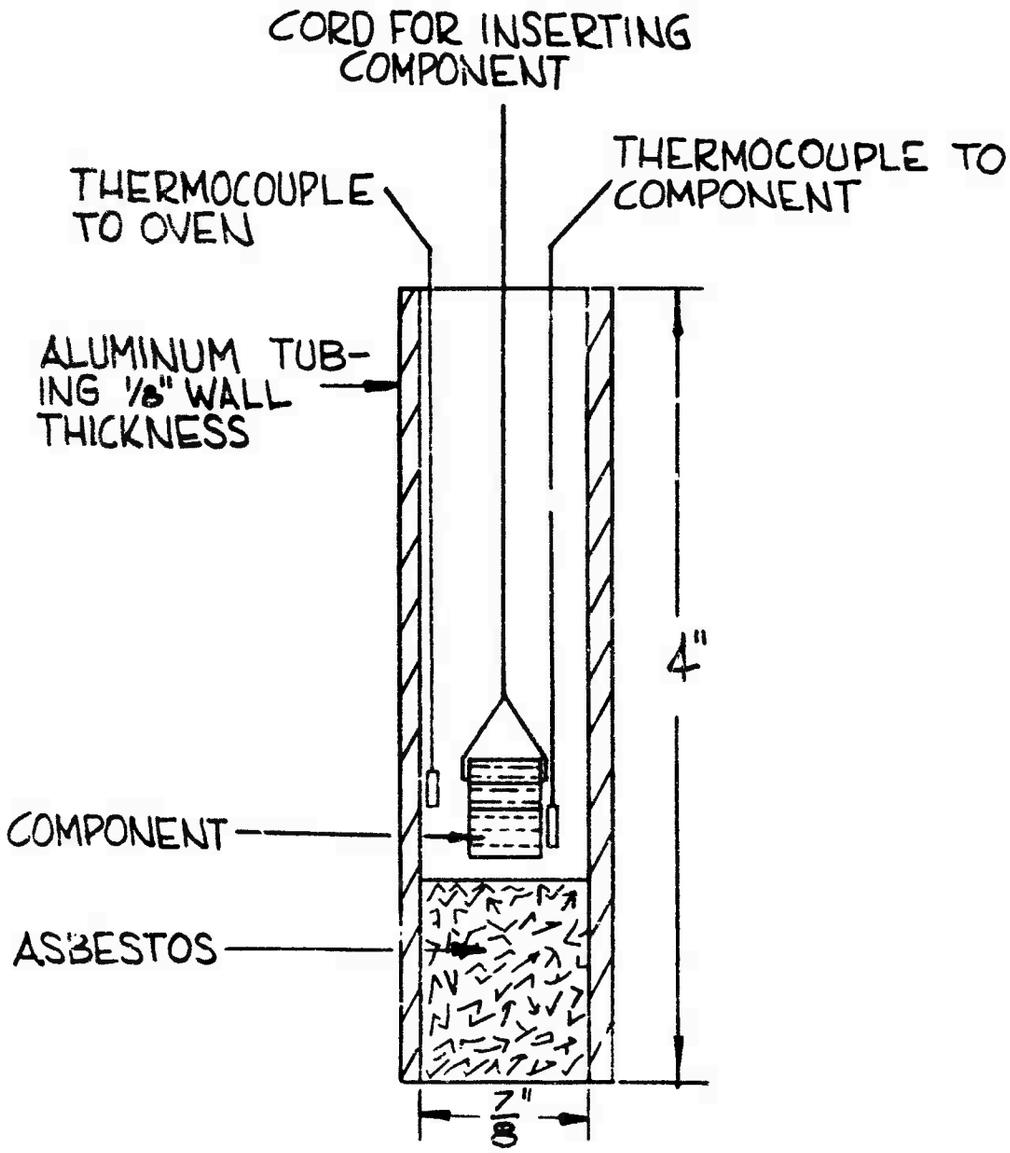


FIGURE 11

SET-UP FOR COOK-OFF TESTS FOR 37MM ROUND IN PREHEATED OVEN (VERTICAL)

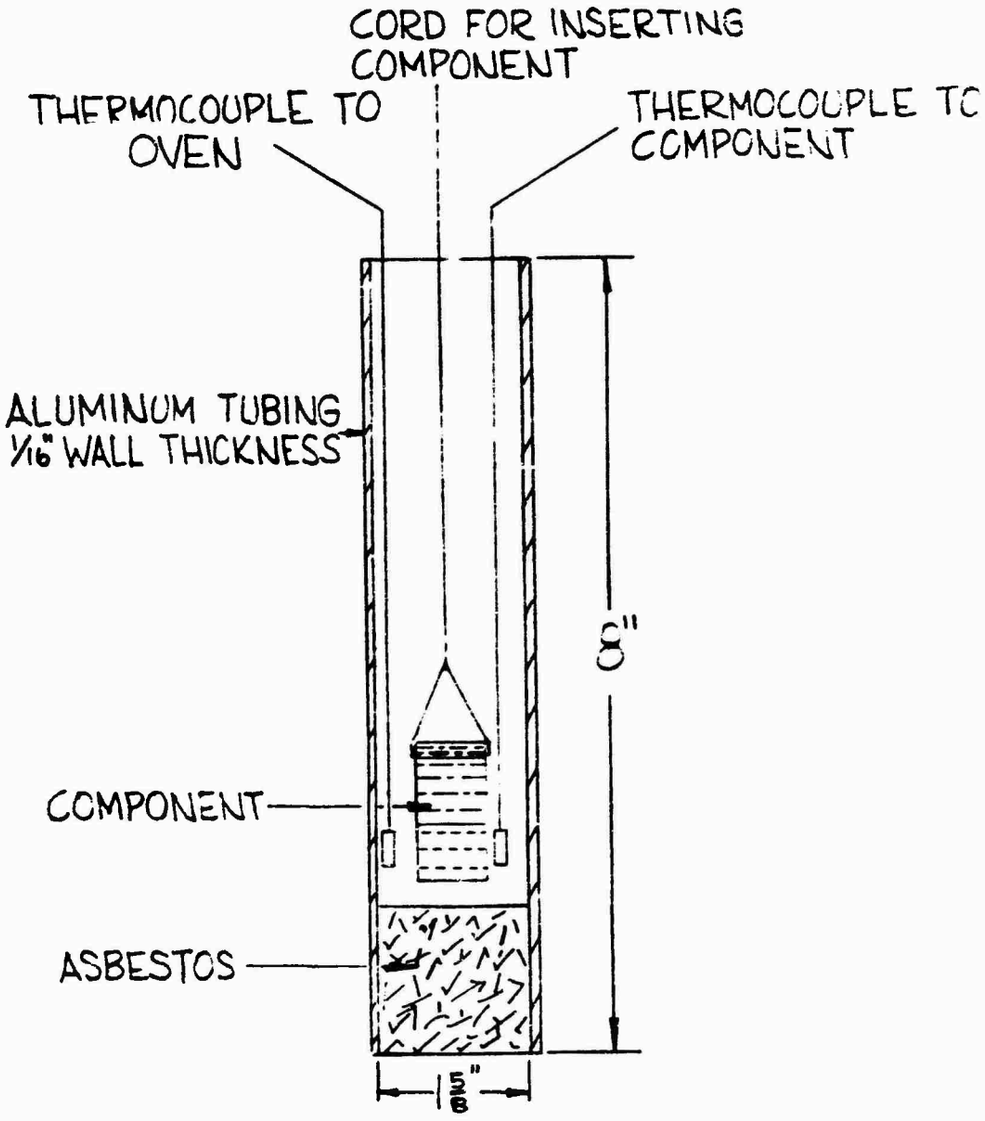


TUBING WRAPPED WITH NICHROME WIRE HEATING COIL AND ASBESTOS PAPER.

COMPONENTS TESTED WERE: BASE AND NOSE FUZES.

FIGURE 12

SET-UP FOR COOK-OFF TESTS OF 37MM COMPONENTS



TUBING WRAPPED WITH NICHROME WIRE HEATING COIL AND ASBESTOS PAPER

COMPONENTS TESTED WERE:
COMPLETE PRIMER, PRIMER HEAD ASSEMBLY, PRIMER LOADING ASSEMBLY, COMPLETE TRACER AND PROPELLANT

FIGURE 13

SET-UP FOR COOK-OFF TESTS OF 37MM COMPONENTS